Deployment after limb salvage for high-energy lower-extremity trauma

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BACKGROUND: Many wounded warriors experienced high-energy lower-extremity trauma (HELET) that may be limb threatening. Volumetric muscle loss, posttraumatic osteoarthritis, nerve injuries, and pain may severely limit physical function. Several wounded warriors express a strong desire to return to their units and be deployed in their original military occupational specialty. We began the return-to-run (RTR) clinical pathway at our institution 2 years ago to facilitate high-performance goals such as these. It involves an energy storing ankle foot orthosis, the intrepid dynamic exoskeletal orthosis in combination with high-intensity, progression-oriented rehabilitation. We sought to determine the rate of deployment or predeployment training after participation in this noninvasive intervention.

METHODS: A retrospective analysis of the RTR database was performed to determine the rate of deployment or predeployment training among those service members who began participation in the RTR between November of 2009 and March of 2011. Medical records were reviewed for demographics, injury, surgical data, and major complications. Requests for delayed amputation were recorded, and charts were reviewed to determine if patients eventually elected to proceed with amputation or if they chose to continue with limb salvage.

RESULTS: Between November 2009 and March 2011, 87 service members completed the RTR. Of these, 17 (19.5%) have been deployed to combat or are in predeployment training. Sixteen serve in combat arms (nine Special Forces, four infantry/ranger, two combat engineers, and one gunner), and one is a member of the military intelligence community. Fifteen patients sustained their injuries as a result of HELET (four gunshot, five motor vehicle collisions, four explosions, one parachute injury, and one fall from height), one had idiopathic avascular necrosis of the talus, and one had an iatrogenic nerve injury after pelvic surgery. Six of the patients underwent circular external fixation, five received joint fusions (three ankle, two subtalar joint), and nine had major nerve injuries. Four initially desired amputation of their injured limb but have subsequently countermanded their request.

CONCLUSION: Returning to high-level physical function after HELET is challenging. After implementation of the RTR clinical pathway with the intrepid dynamic exoskeletal orthosis, 19.5% of wounded warriors treated with the RTR have been deployed or will be deployed in the coming year. (*J Trauma Acute Care Surg*. 2012;73: S112–S115. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic study, level V.

KEY WORDS: Limb salvage; high-energy lower-extremity trauma; energy storing ankle foot orthosis; high-intensity progression-oriented rehabilitation.

Musculoskeletal wounds are the most frequent injuries sustained in combat, and open fractures of the lower extremity are particularly prevalent.[1] These are complex wounds, typically complicated by severe soft tissue and neurovascular injury, volumetric muscle loss, and chronic pain.[2–4] These issues not only challenge the surgeons managing the wounds but also place substantial constraints on rehabilitation and may hinder functional performance.[5] After limb-threatening injury, many active duty service members want to know if they will be able to continue on active duty and if they will be able to deploy with their units in the future. Published return-to-duty rates in the current conflicts of Operation Enduring Freedom and Operation Iraqi Freedom are low, with only 16.5% of amputees and 16% of those with severe type III open tibia fractures having returned to duty.[6,7] There are no reports of return to deployment after severe lower-extremity injury in the literature.

We have instituted a novel orthotic and rehabilitation initiative at our institution to provide care to wounded warriors undergoing limb salvage.[8,9] The return-to-run (RTR) clinical pathway incorporates a custom, carbon fiber energy storage and return ankle foot orthosis, the intrepid dynamic exoskeletal orthosis (IDEO), with a high-intensity sports medicine–based rehabilitation program. Briefly, the RTR begins very early in the course of the patient's treatment, even if full weight bearing has not been authorized or the patient is using a circular external fixator. At this point in the patient's care, rehabilitation is focused on strength, horizontal plyometrics, and run retraining. When full weight bearing is authorized and circular external fixation has been removed, the patient is fit with an IDEO. At this point, the patient progresses to more dynamic impact

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This study was presented at the Advanced Technology Applications for Combat Casualty Care Conference in Fort Lauderdale, Florida, August 15–18, 2011.

This study was conducted under a protocol reviewed and approved by the US Army Medical Research and Materiel Command Institutional Review Board and in accordance with the approved protocol.

The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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DOI: 10.1097/TA.0b013e3182606291

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 AUG 2012	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Deployment after limb salvage for high-energy lower-extremity trauma	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Patzkowski J. C., Owens J. G., Blanck R. V., Kirk K. L., Hsu J. R.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**4**	

exercise, vertical plyometrics, strength, agility, and further run retraining. The second portion of the rehabilitation program, that is, while wearing the IDEO, takes on an average of 12 weeks to complete.[8,9] Wear of the IDEO in military uniform can be seen in Figure 1. Initial data demonstrates significant improvements in functional performance using this program with the IDEO when compared with commercially available orthotic devices.[10] In addition, many of these patients have been able to return to running and recreational sports participation.[8] We sought to determine the rate of deployment of military service members who have completed the RTR clinical pathway after limb salvage for high-energy lower-extremity trauma (HELET).

PATIENTS AND METHODS

Institutional review board approval was obtained before initiation of this study. The RTR database includes all patients who have elected to participate in the RTR. Participation in the RTR is not part of a research study; rather, this is a unique treatment arm for patients who underwent limb salvage at our institution. The database was queried retrospectively to identify all patients who began participation in the RTR between November of 2009 and March of 2011 and either had been deployed to combat or were in predeployment training. Once identified, the outpatient medical records of these service members were evaluated to determine sex, age, date of injury, mechanism of injury, type of injury, treatment, major complications, request for delayed amputation, whether delayed amputation was performed, and military occupational specialty.

RESULTS

Between November of 2009 and March of 2011, 91 patients had elected to participate in the RTR. Of these, 87 completed the entire program, and at a minimum of 1-year follow-up, 17 male patients (19.5%) with a mean age of 31.4 years were found to have been deployed or were in predeployment training. All 17 have maintained their original military occupational specialty, and 16 serve in the combat arms (nine Special Forces, four infantry/ranger, two combat engineers, and one gunner), with one patient serving in the military intelligence community. One patient is preparing to be deployed for a second time with the Special Forces. Injury characteristics and mechanism of injury are shown in Table 1. Fifteen subjects sustained their injuries as a result of HELET (four gunshots, five motor vehicle collisions, four explosions, one parachute injury, and one fall from height). One patient developed idiopathic avascular necrosis of the talus without a precipitating injury, and one developed a tibial nerve palsy after undergoing periacetabular osteotomy. Six of the patients were treated with circular external fixation, five received joint fusions (three ankle, two subtalar joint), and nine had major nerve injuries, with three reporting absent plantar sensation. Four initially desired amputation of their injured limb but have subsequently countermanded their request and favor limb salvage. Three patients developed osteomyelitis, one of whom also developed a septic knee and deep venous thrombosis.

TABLE 1. Injury Characteristics and Mechanism of Injury

Patient No.	Age, y	Musculoskeletal Injuries	MOI
1	34	Open tibia/fibula fracture, open forefoot fracture	GSW
2	26	Open tibia/fibula fracture, ankle dislocation, multiple midfoot fractures	MV vs. Ped
3	33	Open tibia/fibula fracture	GSW
4	35	Compartment syndrome	IED
5	30	Open ankle fracture	MVC
6	40	Open ankle fracture-dislocation, talus fracture	Plane crash
7	31	Iliac wing fracture, lumbar spine fracture, lumbosacral plexopathy	GSW
8	36	Peroneal nerve palsy	Parachute injury
9	26	Talus avascular necrosis	Unknown
10	40	Distal tibia fracture	Fall from height
11	38	Calcaneus fracture, fifth metatarsal fracture, ankle fracture, talus fracture	IED
12	26	Calcaneus fracture	GSW
13	26	Open ankle fracture	MVC
14	33	Open tibia/fibula fracture, ankle fracture, multiple midfoot fractures	IED
15	29	Open tibia/fibula fracture, peroneal nerve palsy	IED
16	27	Knee dislocation, popliteal artery injury, peroneal nerve palsy	MCC
17	25	Periacetabular osteotomy, tibial nerve injury	Iatrogenic

GSW, gunshot wound; IED, improvised explosive device; MCC, motorcycle collision; MOI, Mechanism of injury; MV, motor vehicle; MVC, motor vehicle collision; Ped, pedestrian.

Figure 1. Wear of a military uniform with the IDEO.

DISCUSSION

Return to high-level physical function after HELET is challenging. During the current conflicts in Iraq and Afghanistan,

substantial advances in prosthetic technology have been achieved, with presumed increases in the functional performance of amputees.[11] Until recently, orthotic options tailored to the limb salvage population have been nearly nonexistent. With the advent of the IDEO and RTR clinical pathway at our institution,[9] we have witnessed significant improvements in functional performance of our patients who underwent limb salvage and a decrease in requests for delayed amputation.[10]

The ability to return to military duty after HELET is multifactorial and is not easily predicted at any point in a patient's care. Return-to-duty rates in both amputees and those with severe type III open tibia fractures in the current conflicts are relatively low at 16.5% and 16%, respectively.[6,7] When those with isolated injuries were analyzed separately (i.e., those with an isolated transtibial amputation or isolated grade III open tibia fracture without concomitant orthopedic injuries), the return-to-duty rates increased to approximately 22% for both groups.[6,7] In the current series, we did not separate those with unilateral lower-extremity injuries because most of our subjects had multiple unilateral and frequently bilateral injuries. We suspect that the presence of multiple injuries is a predominant factor in why the return-to-deployment rate among this group is not higher, although further study is needed to determine this.

There are no published reports of deployment to combat after amputation or limb salvage in the peer-reviewed literature. The current study is the first to investigate the rate at which military patients who underwent limb salvage participating in the RTR clinical pathway are able to be deployed to a combat setting. In the current investigation, 19.5% of the patients enrolled in the clinical pathway have been deployed or will be deployed within the current year. At this time, we cannot comment on the return-to-duty rate of patients who have completed the RTR, but a separate prospective study is underway that will evaluate this. Four of the patients in the current cohort initially requested amputation of their injured limb in the hopes of improving their functional performance. However, after completion of the clinical pathway, all four of these patients have countermanded their request and desire to continue with limb salvage.

Deployment to combat requires high-level physical function to best ensure the safety of the individual war fighter and the unit as a whole. Service members are exposed to a hostile environment, with the threat of armed combat looming at any time. They are expected to be able to move quickly and respond instantaneously to actual and perceived threats. If a service member is unable to meet these unique and strenuous physical demands, then their presence in a combat zone of operations endangers their own life, as well as the lives of everyone else in their unit. Furthermore, any assistive devices, to include orthotics, must be able to withstand heavy loads and harsh environmental conditions. Before deployment, the IDEO has been optimized for the individual patient's specific diagnosis, activity levels, and potential deployment duties. The device must be able to sustain high-impact forces related to running on uneven surfaces, inclines, and even parachute jumps all with 45 lb to 120 lb of body armor and related combat gear. Each device has been designed specifically to meet the level of durability required by the patient during their deployment. The design of the IDEO also has been influenced by the various shoe wear and boot wear needs of this population. We have found that each service member, especially those within the Special Forces, have particular preferences and needs when it comes to the type of shoe and boot designs that are optimal for their combat activities. The service members have learned how to precisely use the IDEO as a tool to complete their specific deployment objectives. To date, most of the service members returning to combat arms with the use of an IDEO will have an average of two to three devices for backup purposes. In addition to this, they will usually have 6 to 10 extra skin interfaces that are used under the proximal cuff of the device for comfort and protection while operating with it. A copy of the IDEO device for each deployed service member is kept at the Center for the Intrepid (CFI) in case an additional device is required or if changes to the existing device are needed while the patient is in theater. Service members stay in touch with the prosthetist/orthotist via e-mail or phone when necessary for expedited shipment of supplies or devices to their exact location during their deployment.

There are several limitations inherent in this study. This is a retrospective analysis of a small and heterogeneous patient population. At this time, the available evidence does not allow us to determine which patients are best suited to enrollment in the RTR and fitting with an IDEO. We cannot predict which patients will see the largest improvements and we cannot also predict at the start of the program which patients will likely be able to deploy at the completion of the clinical pathway. Currently, the RTR clinical pathway and IDEO are unique to our institution, which is a centralized facility that allows these patients to train side by side and incorporates orthopedic surgeons, physiatrists, physical therapists, pain specialists, occupational therapists, prosthetists, and orthotists. Outside this unique setting, we do not know if our results would be duplicated. However, efforts are underway to expand the program and research efforts to other military medical centers, as well as major civilian trauma centers.

The RTR clinical pathway is a unique orthotic and rehabilitation initiative that has demonstrated significant improvements in functional performance and lead to a decrease in requests for delayed amputation.[10] Patients with a multitude of musculoskeletal injuries have been enrolled, to include severe tibia, ankle and calcaneus fractures, posttraumatic osteoarthritis, nerve injuries, volumetric muscle loss, and posterior tibial and Achilles tendon deficiencies. The witnessed improvements in functional performance are likely multifactorial. The IDEO is designed to off-load painful segments of the lower extremity and provide dynamic energy return to those with plantarflexion weakness about the ankle. It also controls range of motion for those with painful, arthritic ankle joints. These attributes likely facilitate performance in the rehabilitation arm of the program and prevent the plateau that may arise when pain or weakness would otherwise prevent a service member from making further progress.

Among those service members who began the RTR between November 2009 and March 2011, 19.5% have been able to be deployed to combat or will do so in the coming year. The rate of deployment reported here exceeds that reported for return to duty among amputees,[7] and those

with severe open tibia fractures that were treated before the start of the RTR,[6] suggesting that the return-to-duty rate of our patient population may be even higher. Further study into this program is warranted, and future research efforts include a prospective study to determine return-to-duty rates and long-term functional outcomes and to determine which patients are best suited for and likely to benefit the most from the RTR.

DISCLOSURE

Funding for STReC from the Combat Casualty Care Research Program.

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